Design of Portable Multi-point Temperature Control Cabinet Based on Single Chip Microcomputer

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Abstract. Being widely used in various fields, temperature control cabinet has increasingly higher design requirements. However, single-point temperature measurement is commonly applied in temperature control cabinets now with relatively simple temperature detection, so the temperature measurement results are easily affected by environmental temperature. To meet the demand for precision temperature measurement, this paper not only introduces an 8-bit STC89C52 single-chip microcomputer with low power consumption and high performance as the core, but also adopts multi-point control temperature measurement mode. Bluetooth technology is combined with multi-relay self-switching to realize the overall temperature intelligent control of the temperature control cabinet with 0 to 99 ℃ as the temperature measurement range, 0.125 ℃ as the accuracy, and 100 ms as the refresh duration. The multi-point temperature measurement and control system designed independently in this paper features a simple structure, low cost, high precision, high stability, operability and portability, which can effectively meet the needs of precision temperature measurement of temperature control cabinets.

Keywords: Single Chip Microcomputer; Temperature Control Cabinet; Multi-point Temperature Measurement; Wireless Communication Technology; Multi Relay.

1. Introduction

With the development of digital control and intelligent control in society, temperature control is more and more popular and critical in all aspects of production and life. In many occasions where temperature control is applied, such as food storerooms, smart homes and buildings, it is essential to collect and control temperature data in a quick, accurate and reliable manner [1]. Traditional temperature control cabinet mostly depends on single-point temperature measurement systems, which will inevitably be affected by ambient temperature. Especially in complex application scenarios such as electromagnetic disturbance, higher requirements are put forward for temperature measurement systems, so it is more important to study reliable and practical multi-point temperature measurement system.

The temperature control cabinet is designed with an STC89C52 single-chip microcomputer as the main control module, and the periphery is composed of a temperature acquisition module based on DS18B20, Bluetooth module, liquid crystal display module, key module, relay drive module, buzzer module and LED indicator lamp module [2]. The temperature measurement range is 0 to 99 ℃, the accuracy is 0.125 ℃, and the refresh duration is 100 ms. Combining the characteristic of the 1-Wire bus interface of DS18B20, this design proposes a multi-point temperature detection scheme based on single chip microcomputer, which can collect and process the temperature data of the temperature control cabinet in real-time, and realize Bluetooth transmission, display, storage and inquiry of data. With the advantages of accurate measurement and simple operation, it can meet the basic requirements for high sensitivity, precision and multifunctional temperature control cabinet.

2. Overall System Design

The system consists of an input module and an output module. The input module consists of three parts. The first part is the temperature detection module, which detects the temperature of the current

environment through multi-point temperature measurement. Compared with single-point temperature measurement, the design accuracy is higher and is not easily interfered by uneven temperature; The second part is the key module, through which you can switch interfaces, set thresholds, switch modes, etc.; The third part is the power supply module, which supplies power to the whole system. The output module consists of three parts. The first part is the display module, which displays the monitored data and the set threshold value through LCD1602; The second part is the relay module, which is controlled by two relays respectively for heating and cooling; The third part is the acousto-optic alarm module, which gives an acousto-optic alarm when the monitoring value is not within the set threshold. In addition, the Bluetooth module used as both input and output is connected to the mobile phone, which can transmit the monitored data to the mobile phone of the user. The user can also send instructions to control the relay and the switching of its mode through the mobile phone, which makes it more convenient. The diagram of the overall system design is shown in Figure 1.

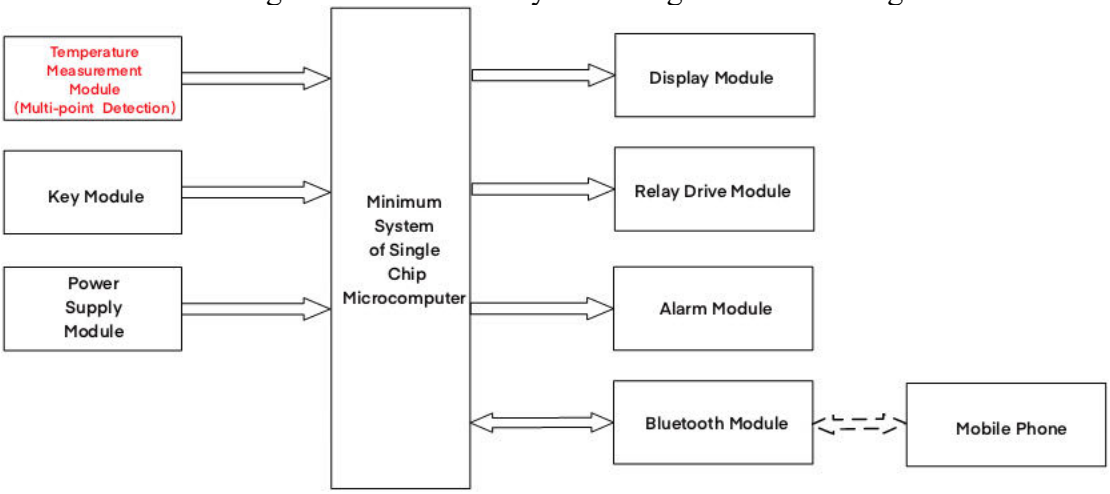

Figure. 1 Overall System Design

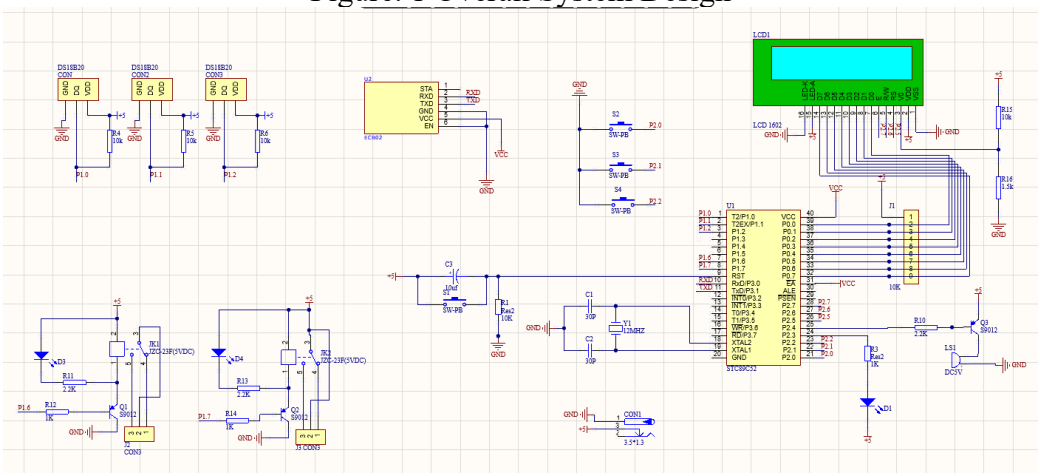

Figure 2 Overall Principle Design

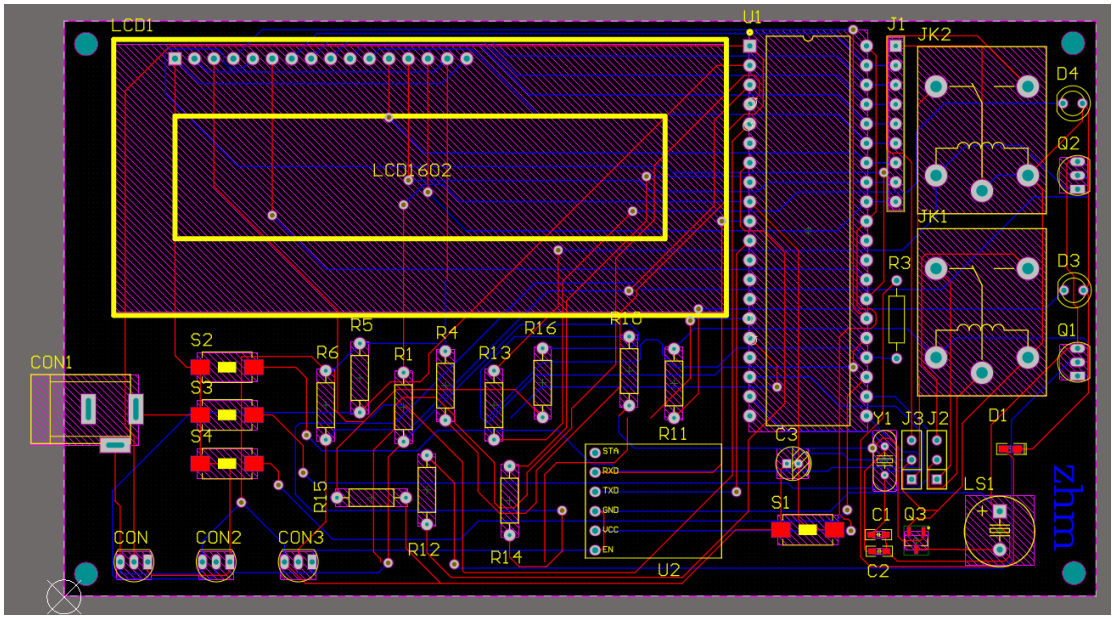

Figure 3 PCB Design

3. System Hardware Design

3.1 Main Control Module

STC89C52 single-chip microcomputer is used as the main control chip with clock circuit and reset circuit in the minimum system. STC89C52 single chip microcomputer is a new anti-interference single-chip microcomputer with high speed and low power introduced by STC MicroTM. The instruction code is fully compatible with the traditional 8051 single-chip microcomputer, with 12 clock/machine cycles and 6 clock/machine cycles selected at will. This single-chip microcomputer has a short development period. Moreover, it is widely used at low price, so STC89C52 single chip microcomputer is selected as the core of the system, with the schematic diagram shown in Figure 4.

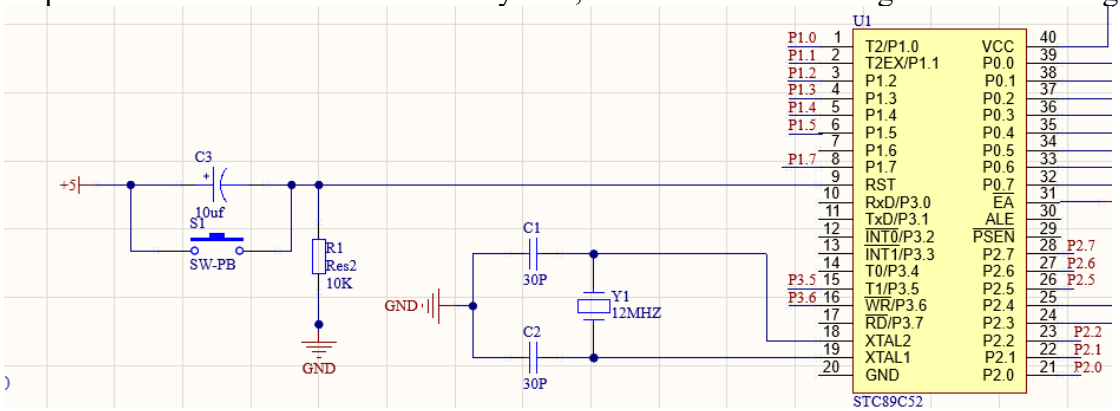

Figure 4 Schematic Diagram of Minimum System of Single Chip Microcomputer

3.2 Temperature Acquisition Module

DS18B20, a networked digital temperature sensor produced by DALLAS Semiconductor Inc., is used for temperature acquisition. As a single-wire temperature sensor with a 3-pin package and a single bus for data communication, DS18B20 can measure the temperature from -55 ℃ to + 125 ℃ with 0.4 ℃ as the measurement error. The module adopts a multi-port parallel driving method for multi-point temperature measurement. The data lines of each DS18B20 are respectively connected to P1.0, P1.1 and P1.2 of the single-chip microcomputer. When the system works, the microprocessor conducts unified parallel operation to each DS18B20 simultaneously. For all DS18B20, the command acceptance and data transmission are synchronized, and the time consumed by inquiring about the

operation of multiple DS18B20 devices is the same as that of a single DS18B20 device, thus achieving the rapid multi-point temperature measurement and meeting the design requirements the temperature measurement system with rigid real-time requirements [3].

STC89C52 is used as the main control body. When the temperature control cabinet is switched on, the DS18B20 temperature sensor sends the multi-point real-time temperature measured in the temperature control cabinet to the single-chip microcomputer for processing. If the single-chip microcomputer judges that the real-time temperature exceeds the threshold range, the relay drives the corresponding electromagnetic relay to work, thus realizing the constant temperature control. The schematic diagram is shown in Figure 5.

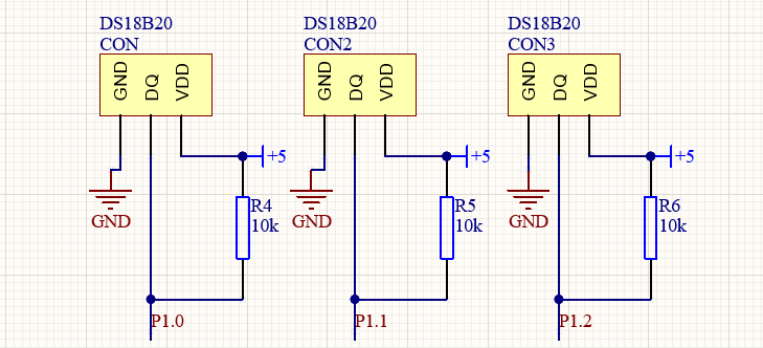

Figure. 5 Schematic Diagram of Temperature Acquisition Module

3.3 Bluetooth Module

ECB02 Bluetooth Module is a low-power serial transmission module, which has the advantages of small size, high performance, high cost performance, low power consumption and strong platform compatibility. The compatible software platforms of the module include the IOS application, Android application, PC application, WeChat, Alipay etc., which are convenient to apply. MCU can communicate with mobile phones, tablets and PC computers through serial port connection modules and realize intelligent wireless control and data acquisition.

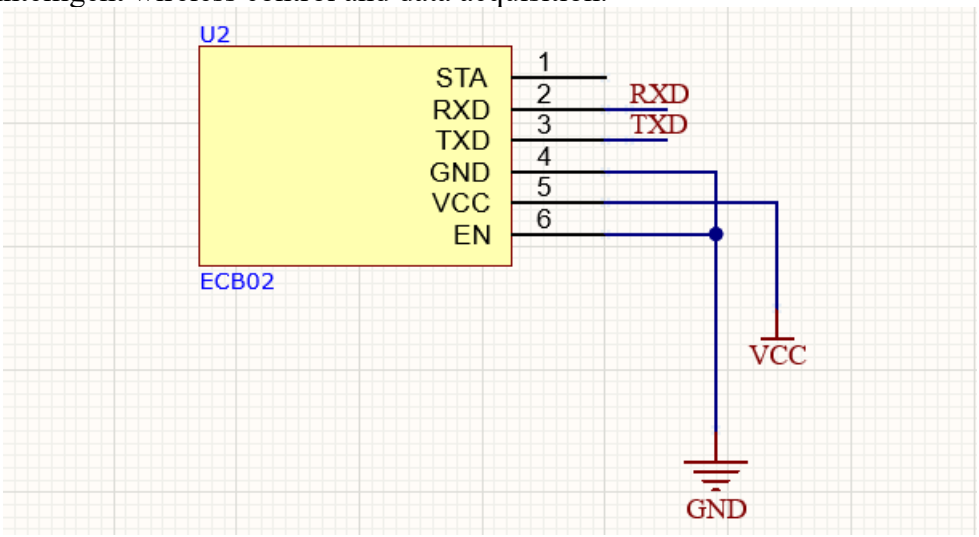

Figure. 6 Bluetooth Schematic Diagram

3.4 Key Module and LCD Module

LCD1602 liquid crystal display is used to display real-time multi-point temperature and average temperature, which is through the key to set. Also known as 1602 character liquid crystal, LCD1602 is a special display letters, numbers, symbols and other dot matrix liquid crystal module [4] with three interfaces. Interface 0 displays three-way temperature measurements and averages. Interface 1 displays the set maximum temperature. Interface 2 displays the set minimum temperature. Key 1 can switch the setting interface. Key 2 can manually control heating and cooling in Interface 0, with +1

as the maximum temperature in Interface 1 and the minimum temperature in the Interface 2. Key 3 can switch the detection mode in Interface 0, with -1 as the maximum temperature in Interface 1 and the minimum temperature in Interface 2. The schematic diagram is shown in Figure 7.

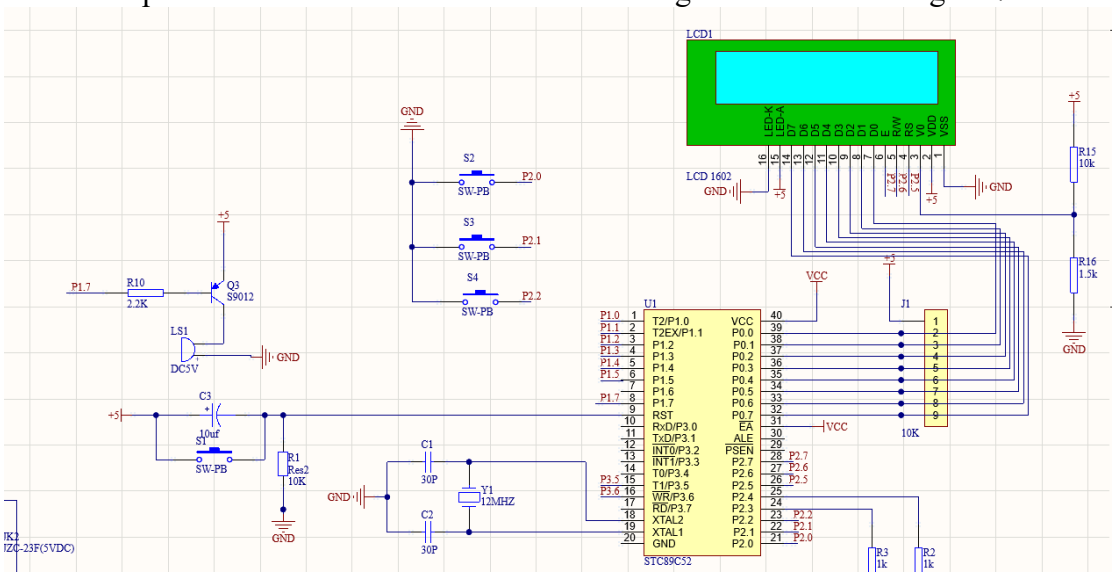

Figure. 7 Schematic Diagram of Key Module and LCD Module

3.5 Relay Drive Module

In this design, two electromagnetic relays JK1 and JK2 are selected. JK1 is connected to the heating sheet. When the temperature is lower than the lower limit of the set value, JK1 is driven to work and heat the temperature control cabinet. JK2 uses a semiconductor refrigeration sheet to provide a cold air source, and two fans are connected outside to achieve heat dissipation and air cooling respectively, so as not to set the threshold too low, resulting in frosting. When the temperature is higher than the upper limit of the set value, JK2 works to cool the temperature control cabinet. PNP triode is used to control the pull-in and disconnection of the relay. When JK1 and JK2 are closed, the corresponding LED indicator lights green to indicate the working state of the relay, with the schematic diagram shown in Figure 8.

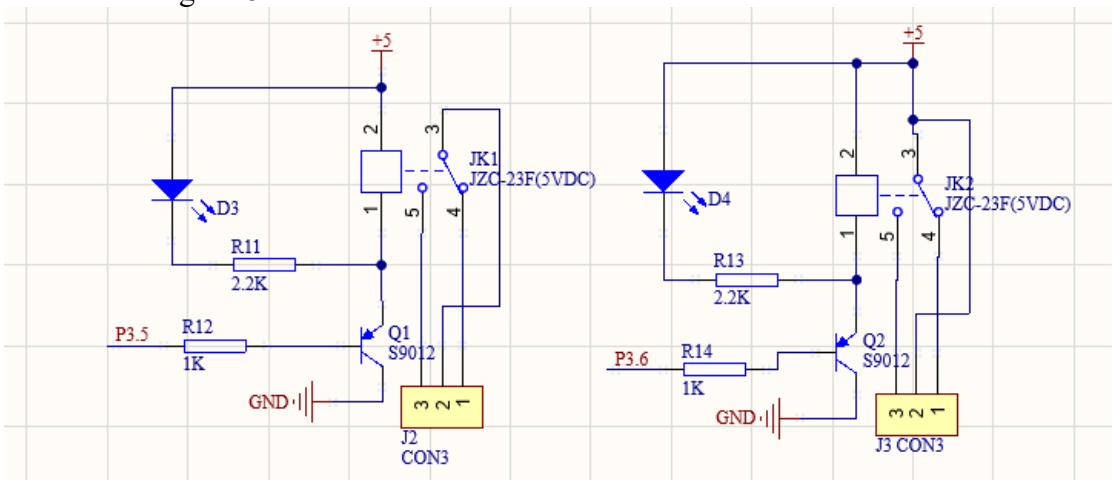

Figure. 8 Schematic Diagram of Relay Drive Module

3.6 Buzzer Module and LED Indicator Module

This design uses a buzzer module and LED indicator module for temperature alarm, in which the buzzer module is composed of a buzzer, PNP triode and power supply. When the temperature exceeds the upper and lower limits, the buzzer beeps and displays a red light to give an alarm [5], with the schematic diagram shown in Figure 7. The alarm circuit of this system is a working buzzer, which outputs effective control signals. As an electronic switch for controlling buzzer interference, Q3 is

switched on at the high level of the FM port, and the buzzer is powered and gives an alarm sound. When the output voltage is low, Q3 turns off and the buzzer stops working, so the system cannot work normally at this time. The schematic diagram of the alarm circuit of the system is shown in Figure. 9. Combined with the Bluetooth module, the user can know in time that the temperature in the locker has been lower or higher than the set threshold range.

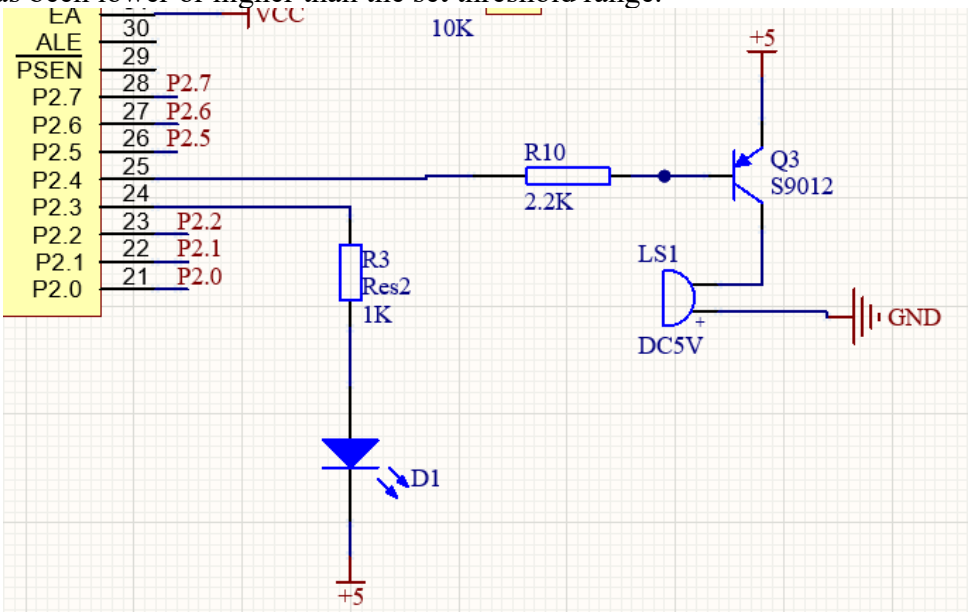

Figure. 9 Schematic Diagram of Buzzer Module and LED Indicator Module

4. Software Design

The software design adopts modular design, which consists of a main program, temperature acquisition subroutine, keyboard subroutine, Bluetooth subroutine and display subroutine. As for the main program, each module is initialized first, and then enters the while main loop. In the main cycle, the first key function is entered, which is mainly divided into two parts. The first part is to call the key scanning function to obtain the key value of the key, and the second part carries out corresponding processing operations through the key value, including switching interfaces, setting thresholds, etc. Then it enters the monitoring function, which mainly obtains the measured value by calling the corresponding driving function, and transmits the monitored data to the mobile phone through the Bluetooth module. The user can also send instructions through the mobile phone, and the equipment executes corresponding processing according to the instructions sent by the user. Then it comes to the display function, which displays the monitoring value and threshold value. Finally, it is a processing function, which mainly judges whether the current temperature is within the set threshold. If the temperature is greater than the set maximum value, it gives an acousto-optic alarm and turns on the refrigeration relay to cool down. If the temperature is less than the set minimum value, it gives an acousto-optic alarm and turns on the heating relay to heat. If the temperature is within the set threshold, it cancels the acousto-optic alarm and turns off the heating and refrigeration relays.

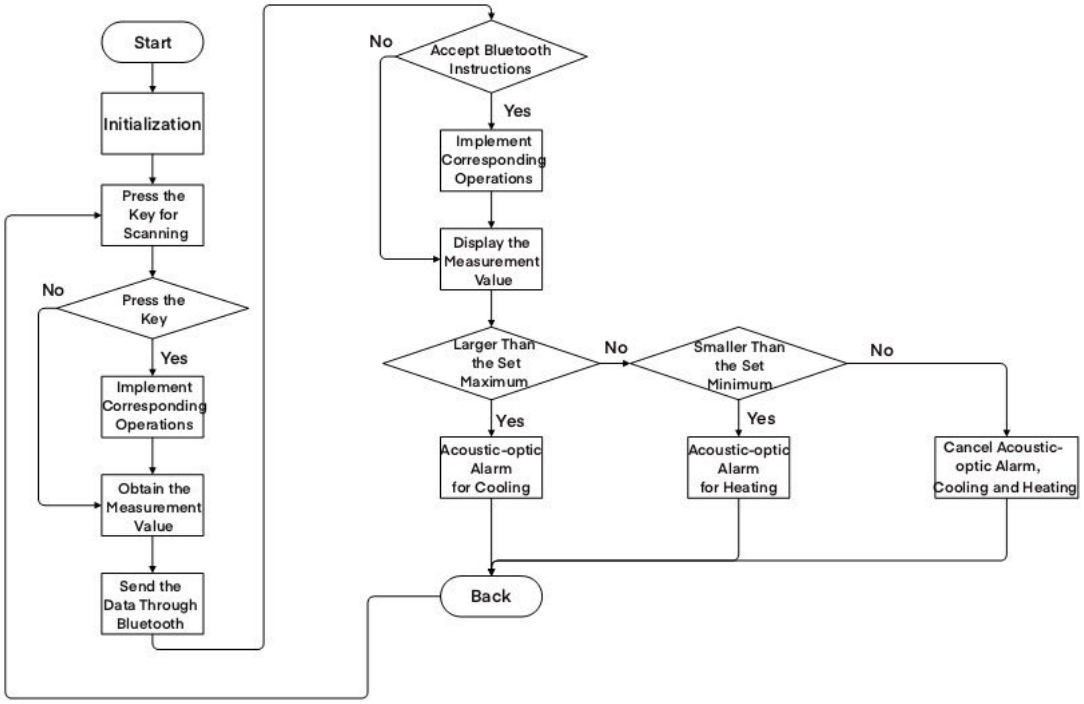

Figure. 10 Flow Chart of Main Program

5. Simulation Test

In this paper, Proteus is used to simulate the circuit schematic diagram and software program, with the C programming language written in advance imported into the AT89C52 single-chip microcomputer of Proteus for circuit simulation. When the temperature changes, the temperature sensor collects a weak electromotive force, that is, the temperature is converted into an electrical signal. Thus, we can read or write information from the DSI8B20 temperature sensor. Next, the single-chip microcomputer can read the data collected by the DS18B20 temperature sensor through the single-wire interface [6].

Table 1 System Temperature Monitoring Experiment

Number of Experiments	Temperature 1	Temperature 2	Temperature 3	Average Temperature	Alarm or not
1	16	20	19	18.3	Yes
2	18	20	24	20.6	No
3	22	24	27	24.3	No
4	25	26	23	24.6	No
5	27	31	28	28.6	No
6	28	31	31	30	No
7	32	33	32	32.3	Yes

Table 1 can detect the accuracy of temperature monitoring of the whole system, with temperatures set to 20 ℃ and 30 ℃. When the average temperature is 18.3 ℃, the system will give an alarm when it is lower than 20 ℃ and 30 ℃. When the temperature is 24.3 ℃, the system will not give an alarm if it is higher than the set temperature. When the displayed temperature exceeds the set temperature, the system will give an alarm. A single temperature exceeding the set range will not affect the result, and the alarm state can be reached after many tests. It shows that this system can run normally.

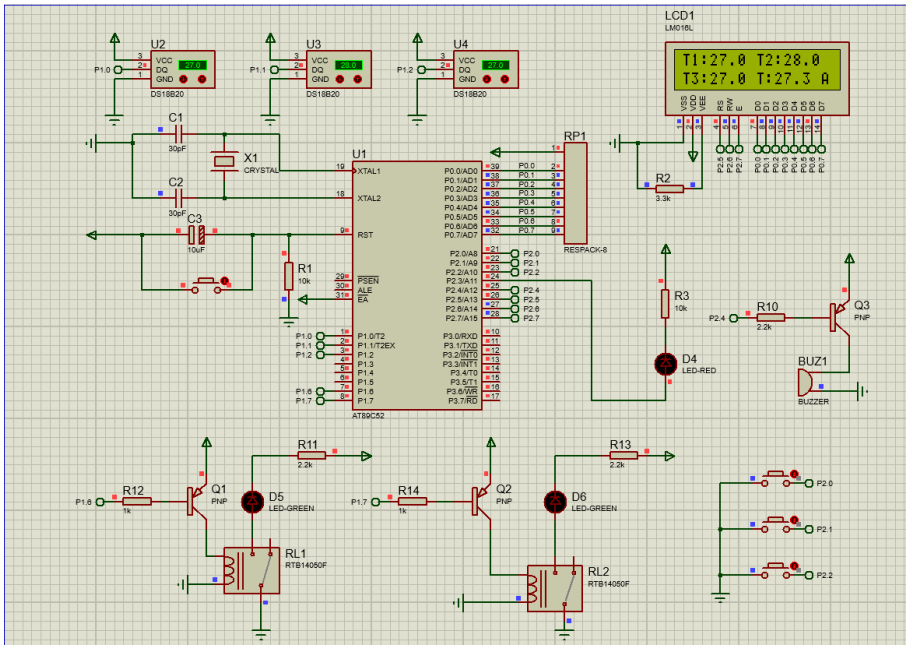

Figure. 11 Simulation Process Diagram

6. Conclusion

This paper designs a Bluetooth multi-point temperature control cabinet based on STM89C52 single-chip microcomputer. The hardware design includes the main control module, temperature acquisition module, Bluetooth module, LCD module, key module, relay drive module, buzzer module and LED indicator module. The software design is mainly to process and control the data collected by the temperature sensor by single-chip microcomputer [7]. Through the analysis of the operation results, when the average temperature is greater or less than the set temperature in many experiments, sound and light alarms will be given. The temperature control cabinet has achieved the functions expected by the design scheme, which can realize intelligent and automatic temperature control, featuring strong safety, high refrigeration and heating efficiency with a wide application prospect.

References

[1] Gao, Y. (2023). Design of wireless thermostat based on SCM. Changjiang Information & Communications, 36(02): 150-153.

[2] Zhu, Z. (2019). Design of temperature acquisition and wireless transmission system based on single chip microcomputer. China Plant Engineering, (08): 105-106.

[3] Qi, W. Y., Meng, Y. H. & Shen, M. (2003). Methods and skills of using DS18B20 for temperature detection. Chinese Journal of Scientific Instrument, (S2): 235-236. DOI:10.19650/j.cnki.cjsi.2003.s2.107.

[4] Tao, R. T. (2022). Design of temperature acquisition system based on LabVIEW and single chip microcomputer. Plant Maintenance Engineering, (17): 128-132. DOI:10.16621/j.cnki.issn1001-0599.2022.09.50.

[5] Bi, T. (2018). Design of temperature alarm system based on AT89C52 single chip microcomputer and DS18B20 sensor. Journal of Fujian Computer, 34(08): 130-131. DOI:10.16707/j.cnki.fjpc.2018.08.064.

[6] Bu, Y. K., Guo, J. M. & Liu, H. Y. (2021). Design and implementation of intelligent fire alarm system based on 51 MCU. Journal of Qilu University of Technology, 35(04): 53-58. DOI:10.16442/j.cnki.qlgydxxb.2021.04.009.

[7] Zhang, C. Y., Wen, H., Li, W. et al. (2023). The intelligent constant temperature cabinet based on single chip microcomputer. Microcomputer Applications, 39(09): 45-49.